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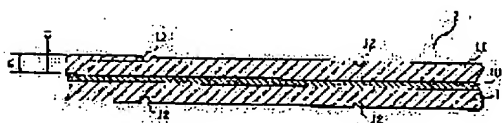
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(54) LITHIUM ION BATTERY

(57)Abstract:

PROBLEM TO BE SOLVED: To increase the capacity of a battery and improve the cycle characteristic by sufficiently impregnating an electrolyte to the center part in the electrolyte permeating direction of a negative electrode.

SOLUTION: Negative electrode active material layers 11 formed of graphite are formed on both surfaces of a core body 10 formed of copper foil, and electrolyte guide grooves 12 are formed on the outer surfaces of the negative electrode active material layers 11 at an interval such that 1.5 grooves are formed per cm. A depth of the electrolyte guide groove 12 is set to 1/8-1/2 of the thickness t2 of the negative electrode active



material layer 11, and a width of the electrolyte groove to 0.1mm-1.0mm. Such a negative electrode 2 is manufactured by applying a slurry negative electrode active material on both surfaces of the core body 10 followed by drying to manufacture the negative electrode active material layers, and compressing the negative electrode active material layers on a roller having projections formed on the surface.

CLAIMS

[Claim(s)]

[Claim 1] The lithium ion battery characterized by forming the electrolytic-solution guide rail in the osmosis direction of said organic nonaqueous electrolyte in the front face of said negative-electrode active material layer in the lithium ion battery equipped with the separator with which the negative-electrode active material layer which consists of the carbon material which emits [occlusion and] a lithium ion has been arranged between the negative electrode prepared in both sides of a foil-like axis, the positive electrode which consists of a lithium content multiple oxide, and said negative electrode and positive electrode, and organic nonaqueous electrolyte.

[Claim 2] The lithium ion battery according to claim 1 characterized by using a graphite as said carbon material.

[Claim 3] Said electrolytic-solution guide rail is a lithium ion battery according to claim 1 or 2 characterized by applying to the other end and being formed from the end of the osmosis direction of said organic nonaqueous electrolyte in the front face of said negative-electrode active material layer.

[Claim 4] It is the lithium ion battery according to claim 1 or 2 which the number of said electrolytic-solution guide rail is 1-5 per 1cm of plates, and the depth of an electrolytic-solution guide rail is 1/2 or less [of the thickness of a negative-electrode active material layer / 1/8 or more], and is characterized by the width of face of an electrolytic-solution guide rail being 0.1mm or more 1mm or less.

[Claim 5] Said electrolytic-solution guide rail is a lithium ion battery according to claim 1 characterized by being formed by compressing said active material layer with the roller with which the projection was formed in the front face.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the lithium ion battery with which the graphite is especially used for the above-mentioned negative-electrode active material layer about the lithium ion battery equipped with the separator with which the negative-electrode active material layer which consists of the carbon material which emits [occlusion and] a lithium ion has been arranged between the negative electrode prepared in both sides of a foil-like axis, the positive electrode which consists of a lithium content multiple oxide, and said negative electrode and positive electrode, and organic nonaqueous electrolyte.

[0002]

[Description of the Prior Art] In recent years, the lithium ion battery which has the above-mentioned structure attracts attention as a cell in which high-capacity-izing is possible. Here, at the time of negative-electrode production of this cell, after applying a slurry-like negative-electrode active material to both sides of a foil-like axis and drying to them, an approach which compresses a negative-electrode active material layer with a roller is used. Thus, if a negative-electrode active material layer is compressed, while a carbon material fixes to a foil-like axis and being able to prevent omission of a carbon material, it will be loaded with more active materials into a cell, and much more high capacity-ization of them is attained.

[0003]

[Problem(s) to be Solved by the Invention] However, if a negative-electrode active material layer (negative-electrode active material layer which used the graphite for the negative-electrode active material especially) is compressed like the above, in order that a graphite crystal may carry out orientation in parallel with the front face of a foil-like axis by the compression concerned, the front face of a negative electrode becomes so smooth that it has gloss. For this reason, if a cell is produced using the negative electrode concerned, it will be in the condition that the negative electrode and the separator stuck, and that the electrolytic solution does not sink in will occur frequently into the central part in the electrolytic-solution osmosis direction of a negative electrode. Consequently, the capacity of a cell became small and it had the technical problem that it was moreover inferior to a cycle property.

[0004] This invention is made in consideration of the above-mentioned conventional technical problem, and it aims at offering the lithium ion battery which can aim at high-capacity-izing of a cell, and improvement in a cycle property by fully infiltrating the electrolytic solution also into the central part in the electrolytic-solution osmosis direction of a negative electrode.

[0005]

[Means for Solving the Problem] In order to attain the purpose mentioned above, among this inventions invention according to claim 1 The negative electrode with which the negative-electrode active material layer which consists of the carbon material which emits [occlusion and] a lithium ion was prepared in both sides of a foil-like axis, In the lithium ion battery equipped with the separator arranged between the positive electrode which consists of a lithium content multiple oxide, and said negative electrode and positive electrode, and organic nonaqueous electrolyte, it is characterized by forming the electrolytic-solution guide rail in the osmosis direction of said organic nonaqueous electrolyte in the front face of said negative-electrode active material layer.

[0006] If it is the above-mentioned configuration, since it will not be in the condition that the negative electrode and the separator stuck, in the part in which the electrolytic-solution guide rail is formed, the electrolytic solution will sink also into the central part in the electrolytic-solution osmosis direction of a negative electrode through an electrolytic-solution guide rail. Therefore, since the electrolytic solution permeates on the surface of [whole] a negative electrode, it is avoidable that un-arranging, such as a fall of the capacity of a cell and a fall of a cycle property, arise.

[0007] Moreover, invention according to claim 2 is characterized by using a graphite as a carbon material among the configurations of invention according to claim 1. If a graphite is used as a carbon material, since the front face of a negative electrode will tend [especially] to become smooth, the above-mentioned operation and effectiveness will be demonstrated further.

[0008] Moreover, invention according to claim 3 is characterized by applying to the other end from the end of the osmosis direction of the organic nonaqueous electrolyte in the front face of a negative-electrode active material layer, and forming the electrolytic-solution guide rail in the configuration of invention according to claim 1 or 2. With such a configuration, the above-mentioned operation and effectiveness will be demonstrated still more smoothly.

[0009] Moreover, invention according to claim 4 is characterized by having regulated the depth of an electrolytic-solution guide rail or less [of the thickness of a negative-electrode active material layer / $1/8$ or more] to $1/2$, and regulating the width of face of an electrolytic-solution guide rail for the number of an electrolytic-solution guide rail to 0.1mm or more 1mm or less in the configuration of invention according to claim 1 or 2, 1-5 per 1cm of plates, respectively. thus, if the number of an electrolytic-solution guide rail, the depth of an electrolytic-solution guide rail, and the width of face of an electrolytic-solution guide rail are regulated, the above-mentioned operation and effectiveness will be further alike, and will be demonstrated. This is

considered to be based on the reason shown below.

[0010] That is, the number of an electrolytic-solution guide rail cannot fully demonstrate effectiveness of this invention by that (that is, an electrolytic-solution guide rail cannot fully demonstrate the operation) to which the surface area of a negative electrode seldom increases, if the depth of less than 1 per 1cm of plates and an electrolytic-solution guide rail is [the width of face of the less than 1/8 and the electrolytic-solution guide rail of the thickness of a negative-electrode active material layer] less than 0.1mm. If the number of an electrolytic-solution guide rail exceeds five per 1cm of plates, and the depth of an electrolytic-solution guide rail, on the other hand, exceeds one half of the thickness of a negative-electrode active material layer or the width of face of an electrolytic-solution guide rail exceeds 1mm, since the irregularity on the front face of a negative electrode will become large, a plate reaction serves as an ununiformity and it is based on the reason a cell property falls.

[0011] Moreover, invention according to claim 5 is characterized by forming an electrolytic-solution guide rail in the configuration of invention according to claim 1 by compressing an active material layer with the roller with which the projection was formed in the front face. Although an approach which forms slitting by a cutter etc. is also considered as an approach of forming an electrolytic-solution guide rail in a front face, since a negative-electrode active material will be shaved by this approach, there is a problem that negative-electrode capacity falls. On the other hand, if an electrolytic-solution guide rail is formed by the approach of compressing a negative-electrode active material layer with the roller with which the projection was formed in the front face like the above, since a negative-electrode active material will be shaved, the problem that negative-electrode capacity falls does not arise. In addition, since it will be pressed by the very big pressure in the part concerned when an electrolytic-solution guide rail is formed by the projection of a roller, the effectiveness (namely, anchor effect) that a carbon material is embedded in an axis is fully demonstrated, and there is effectiveness which can be controlled further about a carbon material being omitted from a negative electrode.

[0012]

[Embodiment of the Invention] The gestalt of operation of this invention is explained below based on drawing 1 · drawing 4 . the sectional view in which drawing 1 shows the lithium ion battery of this invention typically -- it is -- this invention cell of drawing 1 -- LiCoO_2 from -- it consists of the positive electrode 1 which changes, the negative electrode 2 which makes a graphite a subject, the separator 3 which estranges these two electrodes, the positive-electrode lead 4, the negative-electrode lead 5, a

positive-electrode external terminal 6, a negative-electrode can 7, etc. It can take out now to the exterior by making into electrical energy chemical-energy which it is in the condition that the positive electrode 1 and the negative electrode 2 were rolled round by the curled form through the separator 3, holds in the negative-electrode can 7, the electrolytic solution is poured in subsequently to in the negative-electrode can 7, and the negative electrode 2 was connected to the positive-electrode external terminal 6 for the positive electrode 1 through [again] the negative-electrode lead 5 at the negative-electrode can 7 through the positive-electrode lead 4, and was produced inside the cell. In addition, as the above-mentioned electrolytic solution, it is LiPF₆ as a solute to the mixed solvent of ethylene carbonate and diethyl carbonate. What was dissolved at a rate of one mol/l. was used.

[0013] Here, the structure of the above-mentioned negative electrode 2 is explained based on drawing 2 - drawing 4. The front view in which drawing 2 shows the negative electrode before winding, the expansion front view to which drawing 3 expanded the A section of drawing 2, and drawing 4 are the B-B line view sectional views of drawing 3. As shown in drawing 4, the negative-electrode active material layer 11-11 which consists of a graphite is formed in both sides of the axis 10 which consists of copper foil, and electrolytic-solution guide rail 12 -- is formed in the external surface of these negative-electrodes active material layer 11-11 at spacing which becomes 1-5 per cm. The above-mentioned electrolytic-solution guide rail 12 -- Depth t1 Thickness t2 of the negative-electrode active material layer 11 As it is constituted so that it may become 1/2 or less [1/8 or more], and shown in drawing 3, it is the width of face t3 of an electrolytic-solution guide rail. It is constituted so that it may be set to 0.1mm or more 1mm or less. In addition, as shown in drawing 2, the negative-electrode lead 5 is being fixed to the end of a negative electrode 2.

[0014] Such a negative electrode 2 is produced by compressing the above-mentioned negative-electrode active material layer with the roller with which the projection was formed in the front face, after applying a slurry-like negative-electrode active material to both sides of the axis 10 which consists of copper foil, drying to them and producing a negative-electrode active material layer.

[0015] In the mode of the above-mentioned implementation here, although formed from the end in the electrolytic-solution osmosis direction, electrolytic-solution guide rail 12 applying it to the other end, as it does not limit to such structure and is shown in drawing 5, it may be the structure which forms electrolytic-solution guide rail 12 -- only in the plate center section in which the electrolytic solution cannot permeate easily. Moreover, as for this invention, it is needless to say that it is not limited to a cylindrical

cell and can apply to lithium ion batteries of any configurations, such as a carbon button mold cell.

[0016]

[Example] One example of this invention is explained below based on drawing 6 - drawing 10. In addition, in the 2nd example, the optimum value of the width of face of an electrolytic-solution guide rail was investigated, and the optimum value of the depth of an electrolytic-solution guide rail was respectively investigated for the number with the electrolytic-solution guide rail optimal in the 1st example per 1cm of plates in the 3rd example.

[0017] (The 1st example)

(Example 1) The number of an electrolytic-solution guide rail is made into 0.1 per 1cm of plates, and it is the thickness t_2 of a negative-electrode active material layer. The depth t_1 of the receiving electrolytic-solution guide rail Set the rate to one half, and width of face t_3 of an electrolytic-solution guide rail was set to 0.1mm, and also the same cell as the mode of implementation of said invention was produced. Thus, the produced cell is called below this invention cell A1.

[0018] (Examples 2-5) The number of an electrolytic-solution guide rail was made into 0.8 each per 1cm of plates, 1, 3, and 5, and also the same cell as the above-mentioned example 1 was produced. Thus, the produced cell is respectively called below this invention cell A2 - A5.

[0019] (Example of a comparison) As shown in drawing 6 and drawing 7, an electrolytic-solution guide rail was not formed, and also the same cell as the above-mentioned example 1 was produced. In addition, in drawing 6 and drawing 7, the same number as drawing 2 and drawing 4 is attached about the same member. Thus, the produced cell is called the comparison cell X below.

[0020] (Experiment 1) In the above-mentioned this invention cell A1 - A5, since the capacity factor to the initial capacity of the comparison cell X and the degree-of-adhesion ratio to the degree of adhesion of the axis of the comparison cell X and a negative-electrode active material layer were investigated, those results are shown in the following table 1. In addition, initial capacity of the comparison cell X is set to 100 in Table 1, and the degree of adhesion of the axis of the comparison cell X and a negative-electrode active material layer is expressed as 100.

[0021]

[Table 1]

[0022] In this invention cell A1 - A5, compared with the comparison cell X, a capacity factor and a degree-of-adhesion ratio are equivalent, or being more than it is admitted

and it is admitted that especially the number of an electrolytic-solution guide rail has become [the capacity factor and the degree-of-adhesion ratio] very high in one - five this invention cell A3 per 1cm of plates - A5 so that clearly from the above-mentioned table 1. Therefore, as for the number of an electrolytic-solution guide rail, from the point of a capacity factor and a degree-of-adhesion ratio, it is desirable that it is one - 5 per 1cm of plates.

[0023] (Experiment 2) Since the above-mentioned this invention cell A1 - A5, and the cycle property in the comparison cell X were investigated, the result is shown in drawing 8 . In addition, experiment conditions are conditions of considering as a full charge by the constant-potential charge of 4.10V, and discharging to discharge-final-voltage 3V by current 1C further, after charging until cell voltage amounts to 4.10V in current 1C.

[0024] It is admitted that the cycle property of A5 [this invention cell A1 -] is improving compared with the comparison cell X, and it is admitted that the cycle property of A5 [especially / this invention cell A3 - A5] is improving extremely so that clearly from drawing 8 . Therefore, as for the number of an electrolytic-solution guide rail, from the point of a cycle property, it is desirable that it is one - 5 per 1cm of plates.

[0025] (The 2nd example)

(Example 1) The number of an electrolytic-solution guide rail is made into three per 1cm of plates, and it is the thickness t2 of a negative-electrode active material layer. The depth t1 of the receiving electrolytic-solution guide rail A rate is set to one half and it is the width of face t3 of an electrolytic-solution guide rail. It was referred to as 0.07mm, and also the same cell as the mode of implementation of said invention was produced. Thus, the produced cell is called below this invention cell B1.

[0026] (Examples 2-5) Width of face t3 of an electrolytic-solution guide rail It was referred to as 0.1mm each, 0.5mm, 1mm, and 1.3mm, and also the same cell as the above-mentioned example 1 was produced. Thus, the produced cell is respectively called below this invention cell B-2 - B5.

[0027] (Example of a comparison) As an example of a comparison, the comparison cell X shown in the example of a comparison of said 1st example was used.

[0028] (Experiment 1) In the above-mentioned this invention cell B1 - B5, since the capacity factor to the initial capacity of the comparison cell X and the degree-of-adhesion ratio to the degree of adhesion of the axis of the comparison cell X and a negative-electrode active material layer were investigated, those results are shown in the following table 2. In addition, initial capacity of the comparison cell X is set to 100 in Table 2, and the degree of adhesion of the axis of the comparison cell X and

a negative-electrode active material layer is expressed as 100.

[0029]

[Table 2]

[0030] In this invention cell B1 - B5, compared with the comparison cell X, a capacity factor and a degree-of-adhesion ratio are equivalent, or being more than it is admitted so that clearly from the above-mentioned table 2 (however, in this invention cell B5, the capacity factor is smaller a little than the comparison cell X), and it is especially the width of face t3 of an electrolytic-solution guide rail. In this invention cell B-2 which is 0.1-1mm - B4, it is admitted that the capacity factor and the degree-of-adhesion ratio are very high. Therefore, from the point of a capacity factor and a degree-of-adhesion ratio, it is the width of face t3 of an electrolytic-solution guide rail. It is desirable that it is 0.1-1mm.

[0031] (Experiment 2) Since the above-mentioned this invention cell B1 - B5, and the cycle property in the comparison cell X were investigated, the result is shown in drawing 9. In addition, experiment conditions are the same conditions as the experiment 2 of said 1st example.

[0032] It is admitted that the cycle property of B5 [this invention cell B1 -] is improving compared with the comparison cell X, and it is admitted that the cycle property of B4 [especially / this invention cell B-2 - B4] is improving extremely so that clearly from drawing 9. Therefore, from the point of a cycle property, it is the width of face t3 of an electrolytic-solution guide rail. It is desirable that it is 0.1-1mm.

[0033] (The 3rd example)

(Example 1) The number of an electrolytic-solution guide rail is made into three per 1cm of plates, and it is the thickness t2 of a negative-electrode active material layer. The depth t1 of the receiving electrolytic-solution guide rail A rate is set to two thirds and it is the width of face t3 of an electrolytic-solution guide rail. It was referred to as 0.5mm, and also the same cell as the mode of implementation of said invention was produced. Thus, the produced cell is called below this invention cell C1.

[0034] (Examples 2-5) Thickness t2 of a negative-electrode active material layer The depth t1 of the receiving electrolytic-solution guide rail The rate was set to each 1/2, 1/3, 1/8, and 1/10, and also the same cell as the above-mentioned example 1 was produced. Thus, the produced cell is respectively called below this invention cells C2-C5.

[0035] (Example of a comparison) As an example of a comparison, the comparison cell X shown in the example of a comparison of said 1st example was used.

[0036] (Experiment 1) In the above-mentioned this invention cells C1-C5, since the capacity factor to the initial capacity of the comparison cell X and the

degree-of-adhesion ratio to the degree of adhesion of the axis of the comparison cell X and a negative-electrode active material layer were investigated, those results are shown in the following table 3. In addition, initial capacity of the comparison cell X is set to 100 in Table 3, and the degree of adhesion of the axis of the comparison cell X and a negative-electrode active material layer is expressed as 100.

[0037]

[Table 3]

[0038] By this invention cells C1-C5, it compares with the comparison cell X so that clearly from the above-mentioned table 3. A capacity factor and a degree-of-adhesion ratio are equivalent, or being more than it is admitted. Thickness t2 of (however, the capacity factor being smaller a little than the comparison cell X by this invention cell C1), especially a negative-electrode active material layer The depth t1 of the receiving electrolytic-solution guide rail It is admitted that the rate has become [the capacity factor and the degree-of-adhesion ratio] very high by this invention cells C2-C4 of $1/8 \cdot 1/2$. Therefore, from the point of a capacity factor and a degree-of-adhesion ratio, it is the thickness t2 of a negative-electrode active material layer. The depth t1 of the receiving electrolytic-solution guide rail As for a rate, it is desirable that it is $1/8 \cdot 1/2$.

[0039] (Experiment 2) Since the cycle property in the above-mentioned this invention cells C1-C5 and the comparison cell X was investigated, the result is shown in drawing 10. In addition, experiment conditions are the same conditions as the experiment 2 of said 1st example.

[0040] It is admitted that the cycle property of this invention cells C1-C5 is improving compared with the comparison cell X, and it is admitted that the cycle property of this invention cells [especially] C2-C4 is improving extremely so that clearly from drawing 10. Therefore, from the point of a cycle property, it is the thickness t2 of a negative-electrode active material layer. The depth t1 of the receiving electrolytic-solution guide rail As for a rate, it is desirable that it is $1/8 \cdot 1/2$.

[0041]

[Effect of the Invention] Since the electrolytic solution will sink also into the central part in the electrolytic-solution osmosis direction of a negative electrode through an electrolytic-solution guide rail according to this invention as explained above, while cell capacity increases, the outstanding effectiveness that improvement in a cycle property can be aimed at is done so.